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National Aeronautics and Space Administration

Evaluating Extravehicular Access Options for a Lunar Surface Habitat

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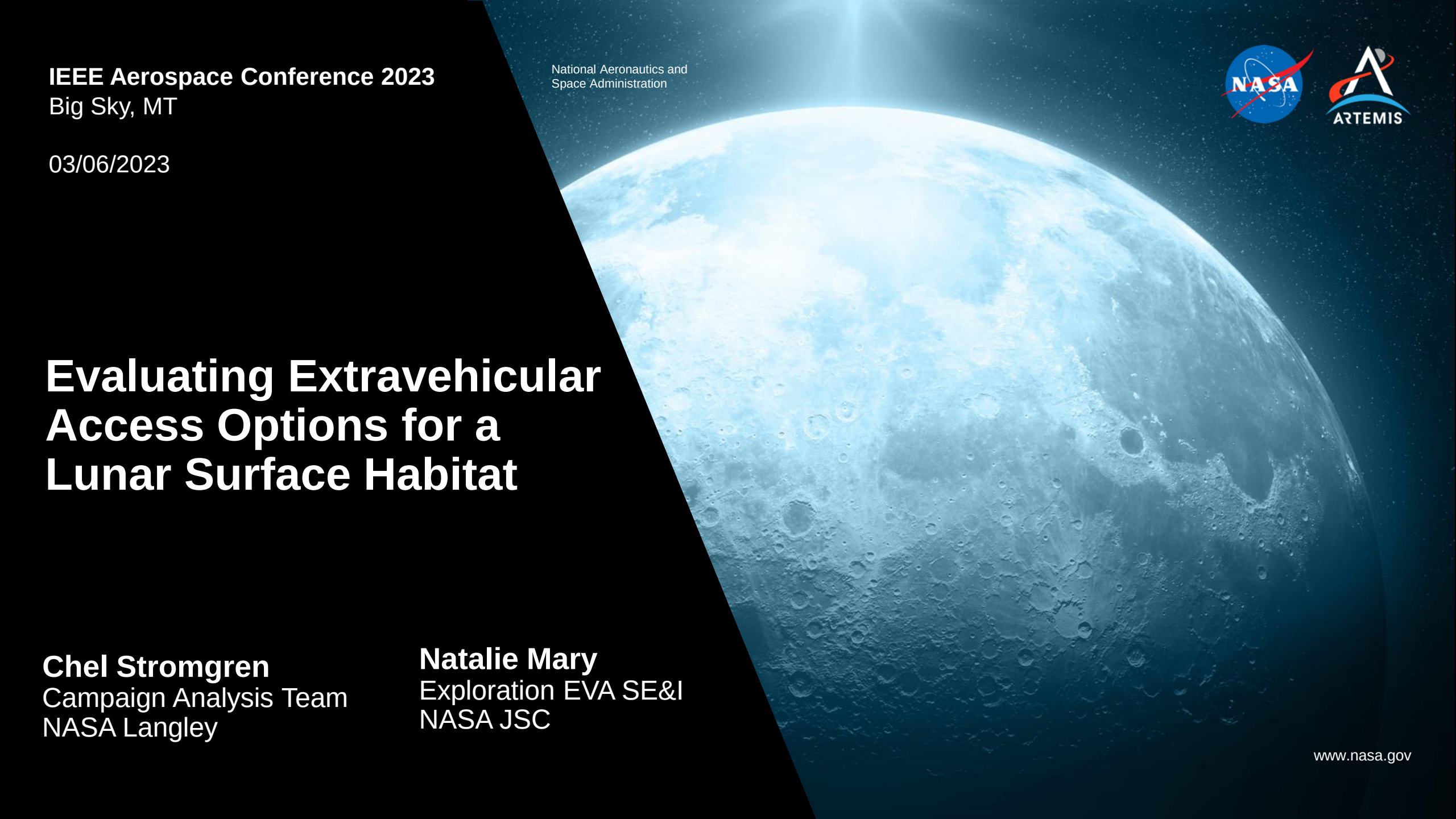


EVA Access on the Moon

- **NASA's exploration plans envision some sort of crew habitat on the surface to expand crew durations on the surface and surface exploration capabilities.**
- **An objective of lunar surface exploration is to maximize the amount of EVA achieved.**
- **Access to the lunar surface from habitable elements is a critical enabling capability, which will have impacts on multiple aspects of the lunar exploration architecture.**
- **The purpose of this study was to compare different options for EVA access from a surface habitat.**
- **Compares three options across various measures of effectiveness:**
  1. Airlock
  2. Suitlock
  3. Suitport- Airlock
- **Also evaluated the effectiveness of an Airlock Gas Recovery system in conjunction with each option.**

Airlock

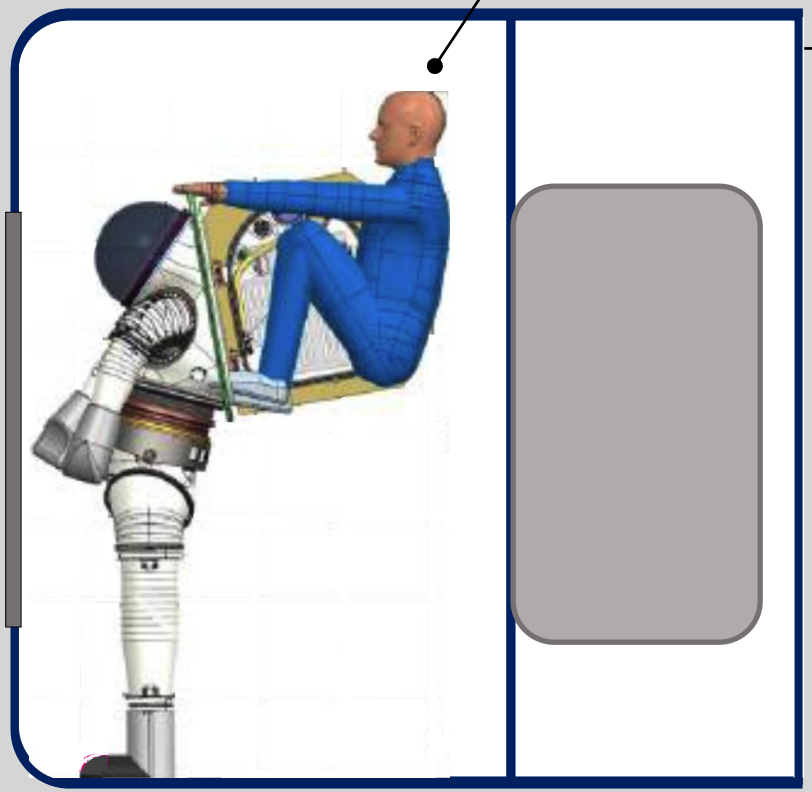
White = Pressurized

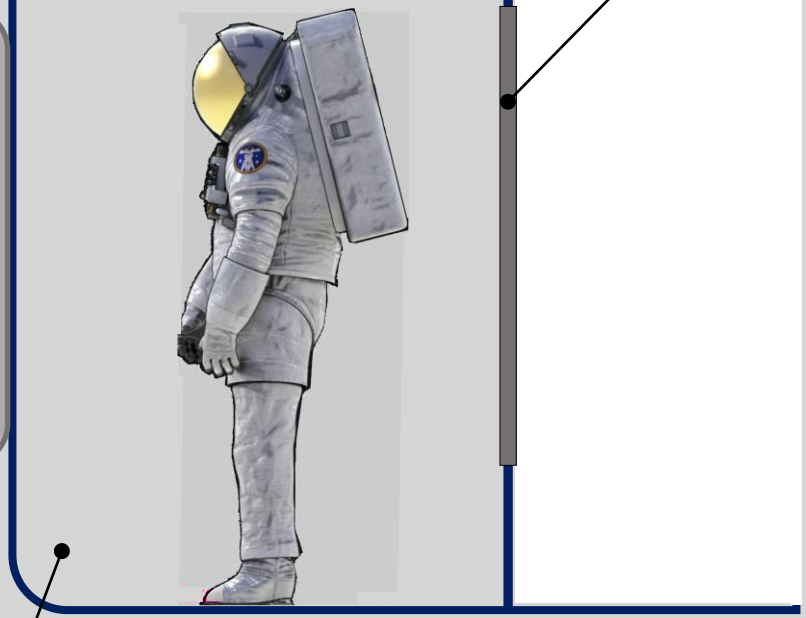
Airlock Volume at Cabin Ambient

Airlock Volume at Vacuum

Hatch Door Bears Pressure Differential During EVA

Crew Entry/Exit to Hab Through Hatch (potential dust)





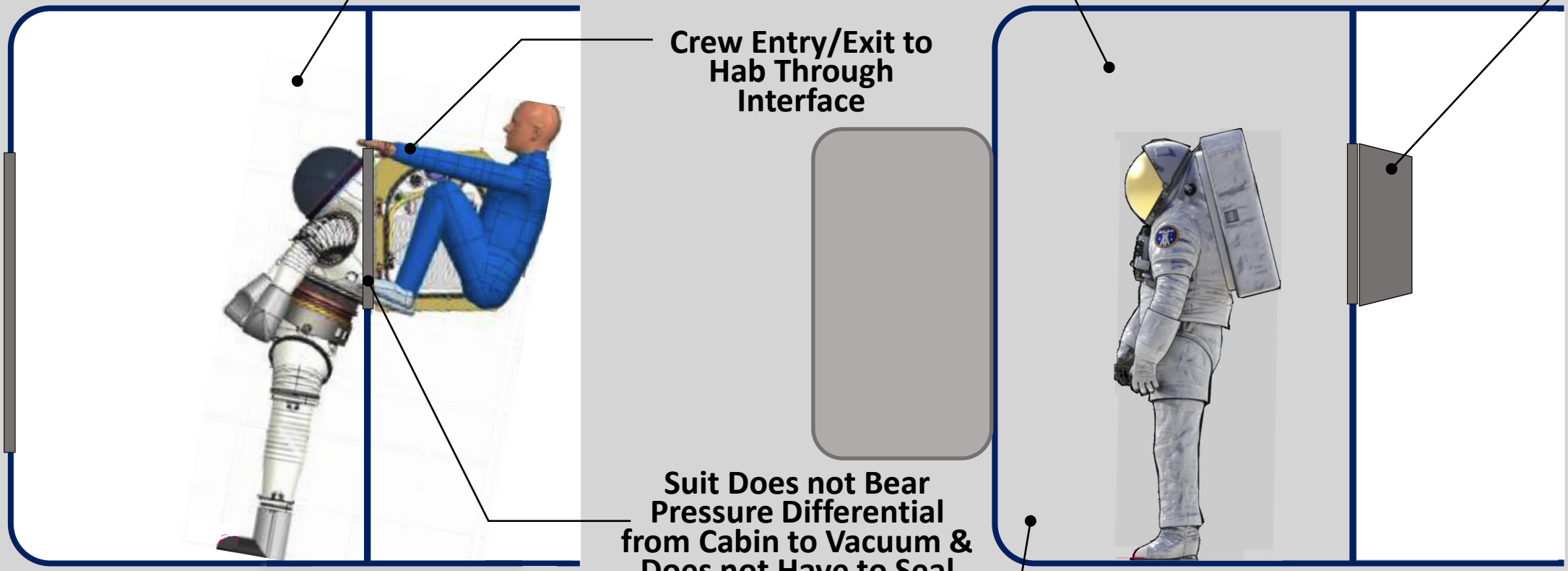
Airlock Volume Must be Repressurized Every EVA

Suit Don and Doff

Entry and Exit

Suitlock

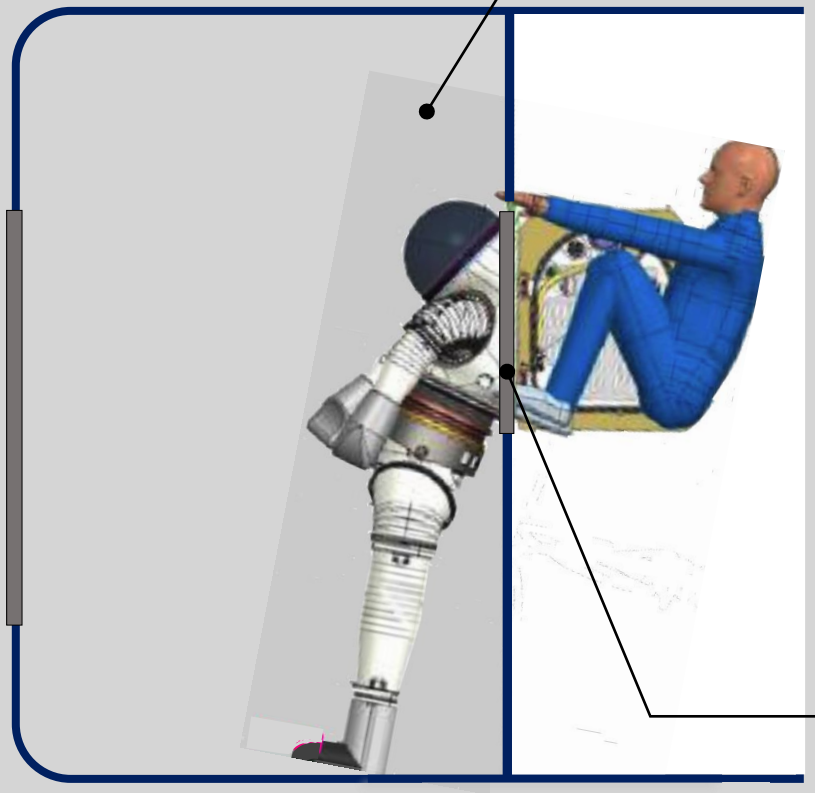
White = Pressurized



Suitport-Airlock

White = Pressurized

Suitport-Airlock Volume at Vacuum* (or at Cabin Ambient)



Suit Bears Pressure Differential During Don/Doff from Cabin to Vacuum and Seals to Bulkhead

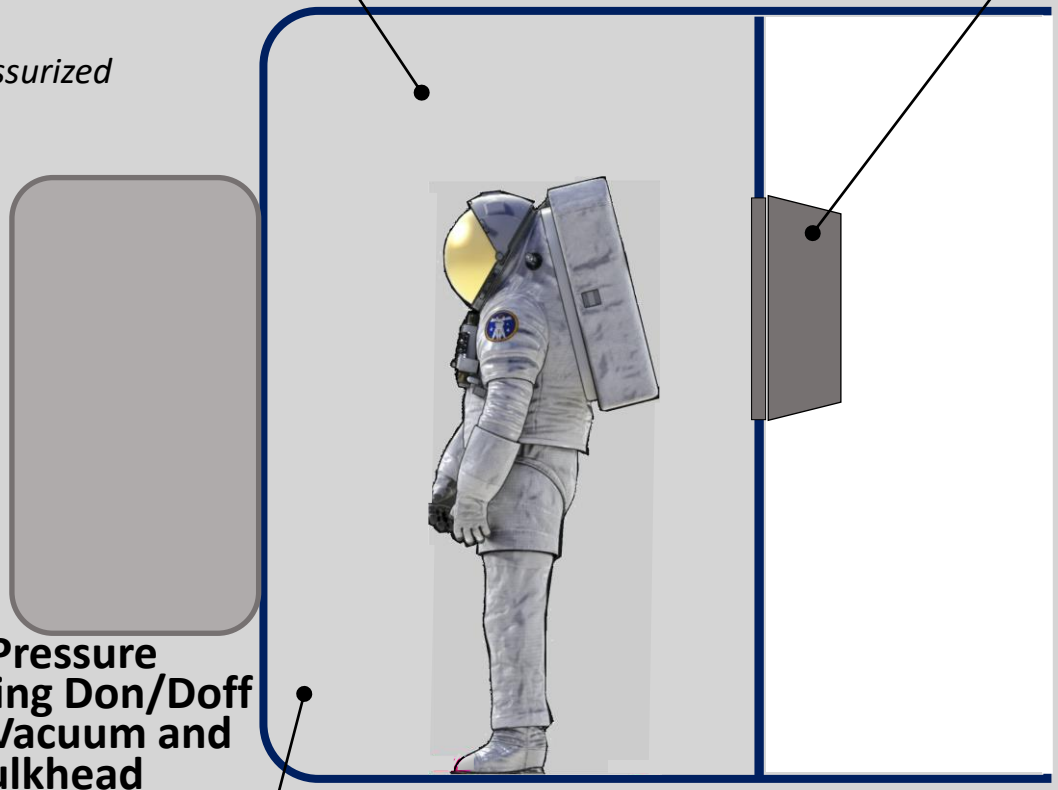
** Interface has a max. pressure delta of 8.2 psia – Suitport-Airlock volume would have to have some residual pressure if cabin pressure > 8.2 psia*

Suit Don and Doff

White = Pressurized

Suitport-airlock Volume at Vacuum

Hatch Cover Bears Pressure Differential During EVA and Between EVAs

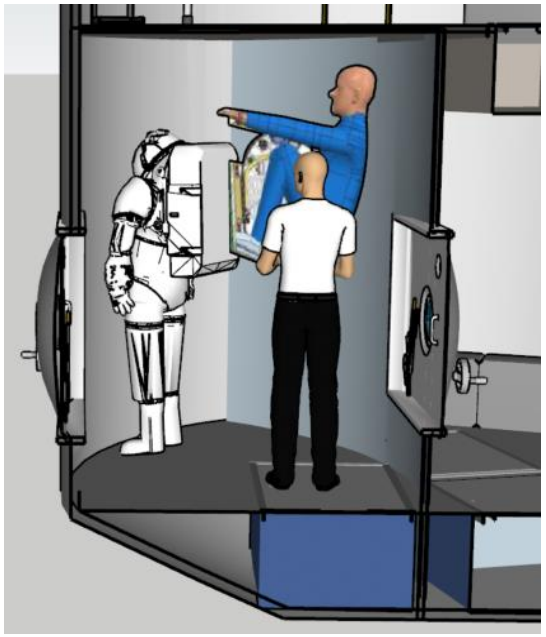


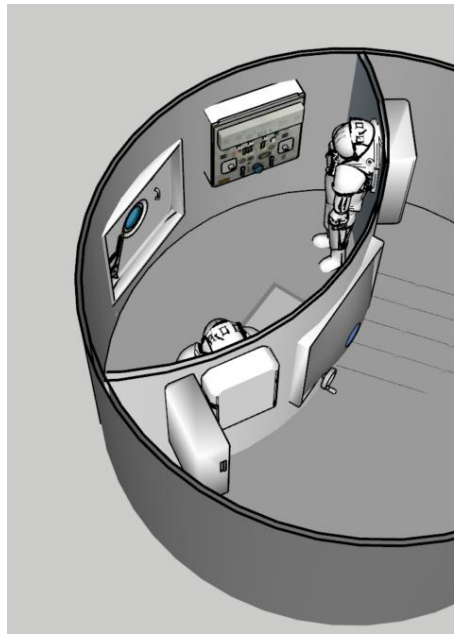
Suitport-airlock Volume Does Not Have to be Repressurized Every EVA

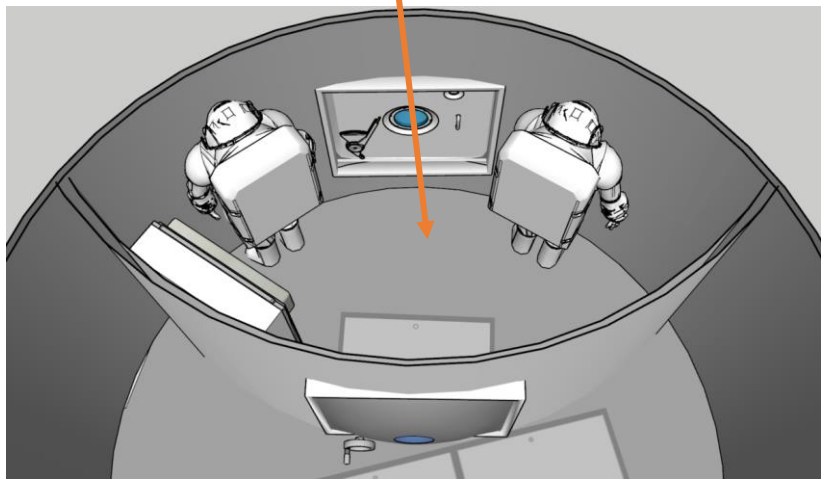
Entry and Exit

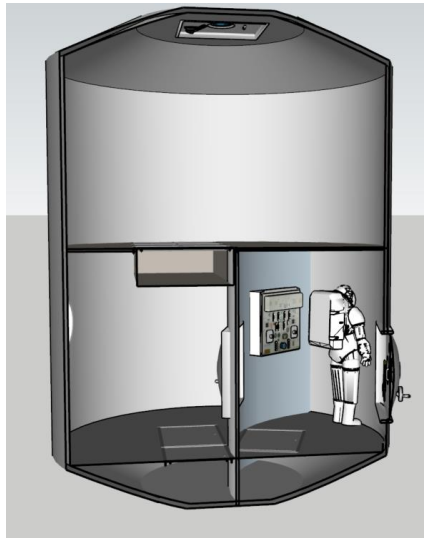
Habitat Airlock

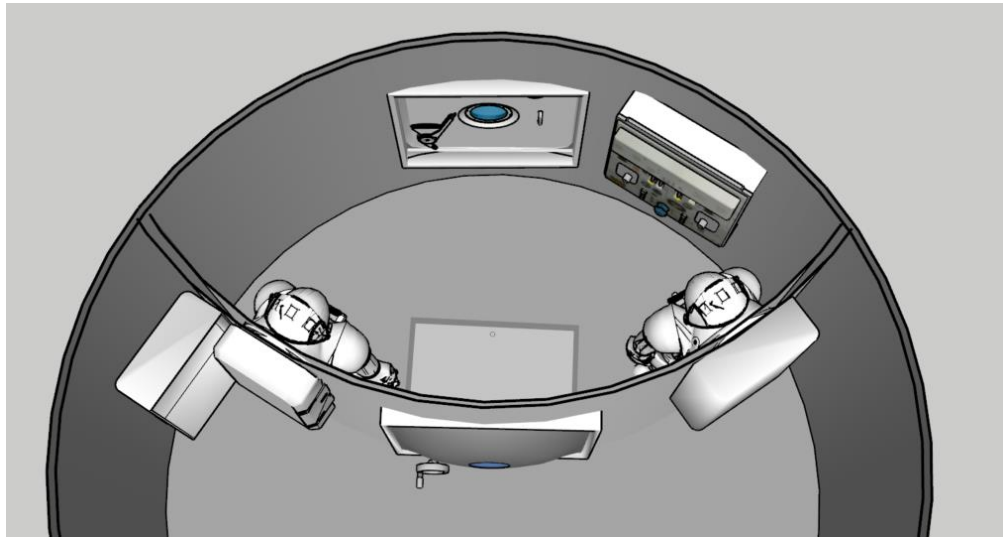
Airlock Volume: 12.0 m^3
Floor Area of Airlock: approx. 4.7 m^2









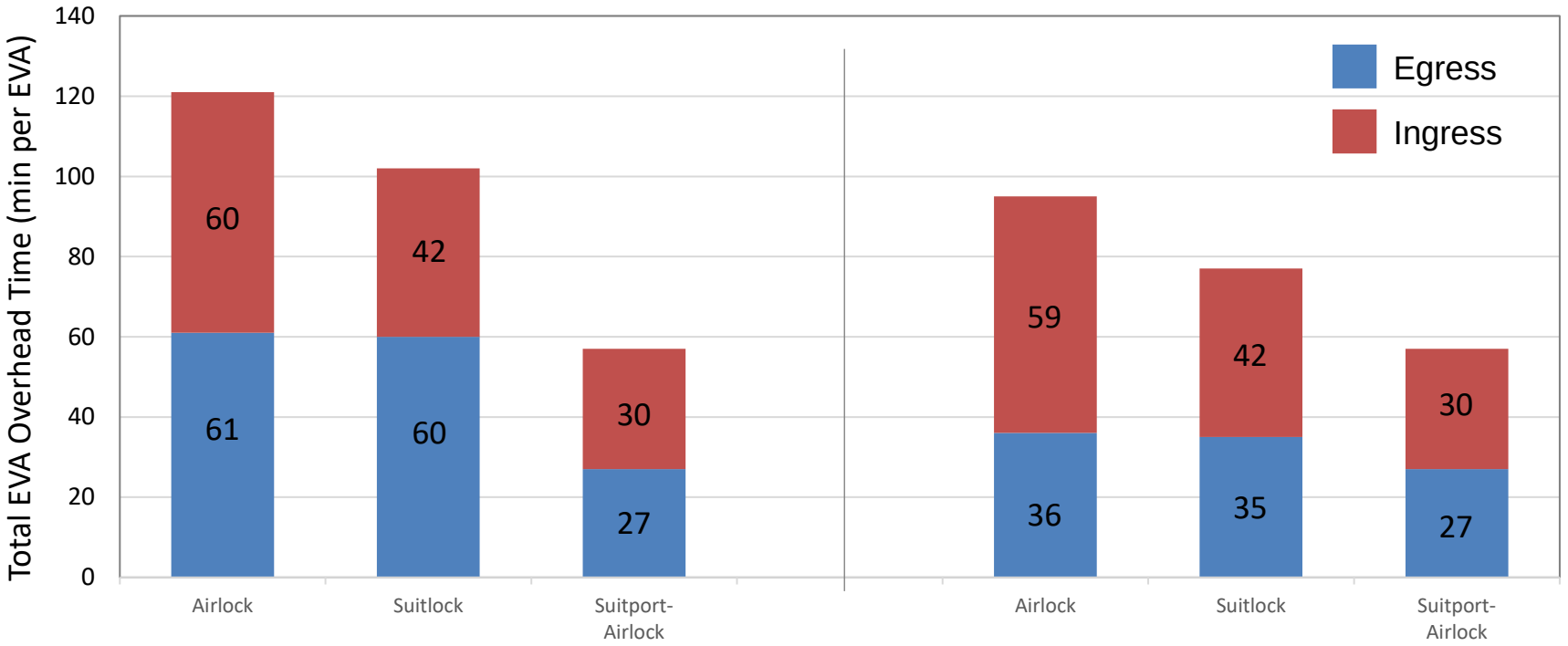


Airlock Atmospheric Recovery System

- **Airlock Atmospheric Recovery (or Airsave) System:**
  - Captures a fraction of airlock gas in lieu of venting pre-EVA
  - Captured gas then used to partially repressurize the airlock post-EVA
- **Fraction of Gas that is reclaimed is a function of pump-down time allowed**
  - Assuming 90% gas recovery for this study
  - 35 min pump down for 8.2 psia

- **Increased power requirements**
- **Some technical questions as to how Airsave would be implemented on a Surface Habitat**
  - Airsave is a relatively mature technology and has been proven on ISS.
  - ISS Airsave pumps airlock gasses into cabin (no additional tanks).
  - With 174 m^3 Pressurized SH volume, this would increase habitat pressure from 8.2 psia to 8.7 psia for the duration of the EVA.
  - If this is an issue, development effort could be more complex and would have to involve external tanks.

EVA Overhead Time Comparison



Comparative Performance						
	Basis for comparison ***95 min per EVA***	Reduces regolith cleaning & IVA hatch time ***77 min per EVA***	Removes depress/repress time for Airlock, reduced regolith cleaning & IVA hatch time ***57 min per EVA***	*Adds Airsave time for Airlock* ***121 min per EVA***	*Adds Airsave time for Airlock* ***102 min per EVA***	*Adds Airsave time for Airlock* ***57 min per EVA***

Decreased Performance — *Baseline* — *Increased Performance*

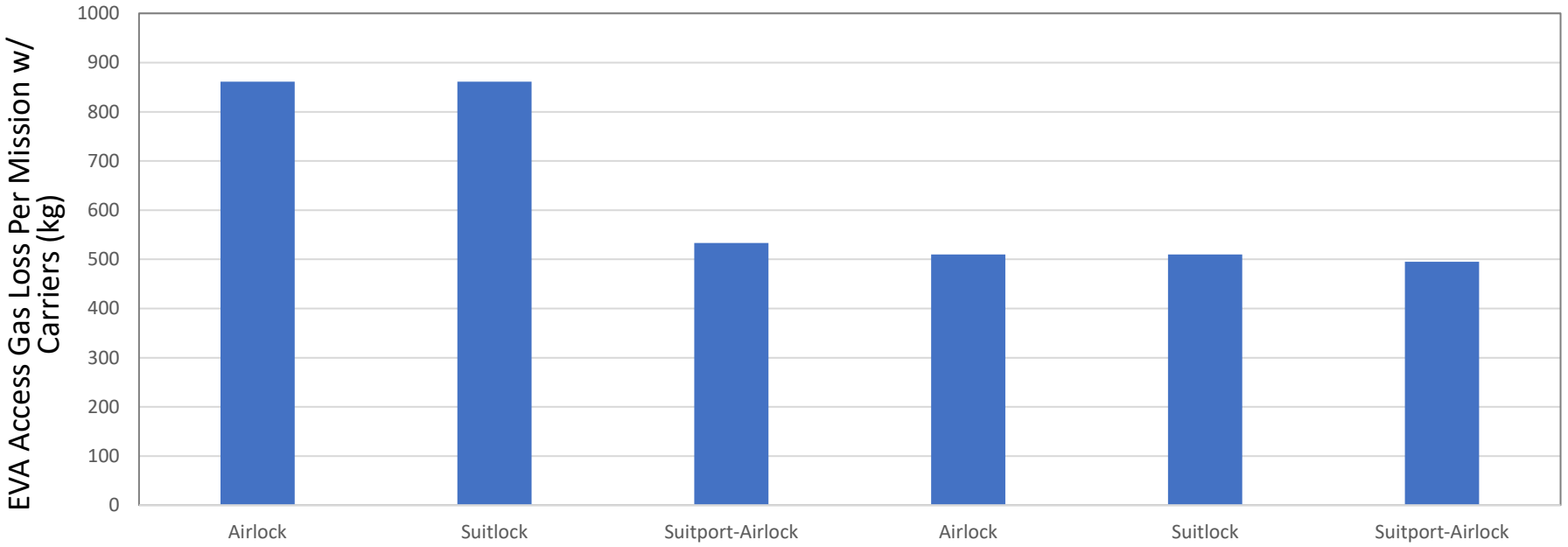
8.2 psia SH Cabin

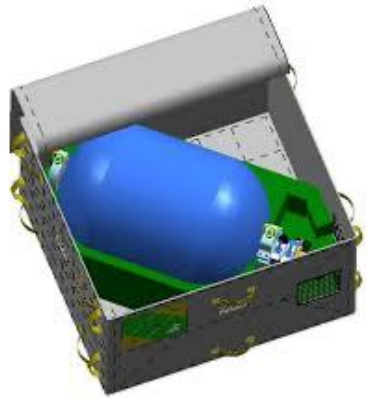
Dust Mitigation Comparison

	Airlock	Suitlock	Suitport-Airlock
Comparative Performance	• Basis of Comparison • Direct crew interaction with dust for all crew EVAs • Dust path into habitat for all logistics ops • Dust path into habitat for all maintenance ops	• Limited dust path into Hab for all crew EVAs • Dust path into habitat for all logistics ops • Dust path into habitat for all maintenance ops	• Limited dust path into habitat for all crew EVAs • Limited dust path into habitat for logistics ops • Dust path into habitat for all maintenance ops

Decreased Performance — *Baseline* — *Increased Performance*

Gas Loss Comparison





	No Airsave			Airsave		
	Airlock	**Suitlock**	**Suitport-Airlock**	**Airlock**	**Suitlock**	**Suitport-Airlock**
Comparative Performance	Basis of Comparison Full airlock gas loss every EVA ***861 kg per mission***	Full airlock gas loss every EVA ***861 g per mission***	*Suitport reduces lost gas, but log + maint operations still require airlock repress* ***533 kg per mission***	Full airlock gas loss every EVA ***510 kg per mission***	Full airlock gas loss every EVA ***510 kg per mission***	Reduced 10% gas when airlock not used ***495 kg per mission***

Decreased Performance — *Baseline* — *Increased Performance*

8.2 psia SH Cabin
28 days in habitat
2 X 2 Crew EVA events per week

Systems Mass Comparison

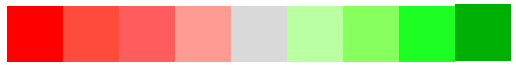
	No Airsave			Airsave		
	Airlock	**Suitlock**	**Suitport-Airlock**	**Airlock**	**Suitlock**	**Suitport-Airlock**
Comparative Performance	Basis of Comparison ***0 kg***	Additional hatches for Suitlock interface in Airlock bulkhead ***Δ +40 kg***	Additional suitport interfaces in Airlock bulkhead + restraints, jumpers, and additional equipment ***Δ +110 kg***	Airsave increases mass by 139 kg ***Δ +139 kg***	Airsave increases mass by 139 kg ***Δ +179 kg***	Airsave increases mass by 139 kg ***Δ +249 kg***

Decreased Performance — *Baseline* — *Increased Performance*

Safety & Mission Assurance Comparison

	Airlock	Suitlock	Suitport-Airlock
Comparative Performance	• Basis of comparison • High EVA overhead time	• Increased associated risk due to increased number hatches and sealing surfaces for Suitlock interface	• Increased risk due to increased complexity and increased number hatches and sealing surfaces for Suitport interface • Continual exposure of EVA suits to pressure differential (risk already exists on rover). • Reduced EVA time (from reduced overhead) reduces DCS risk

Decreased Performance — *Baseline* — *Increased Performance*



Programmatic Comparison

	Airlock	Suitlock	Suitport-Airlock
Comparative Performance	• Basis of comparison • Limited capability and/or technology development required	• Development of suitlock interface required – relatively straightforward • Required modifications to xEMU suit to utilize suitlock • Development would be for SH only • Develop of airlock protocols for risk reduction required	• Requires completed development of suitport interface prior to SH deployment • DDT&E costs required for PR – no additional DDTE cost • Potential schedule impacts from delays • xEMU-SP required to utilize suitports – Airlock could be used in interim if xEMU-SP is delayed

Decreased Performance — *Baseline* — *Increased Performance*

Summary

No Airsave

	EVA Overhead Time	Dust Mitigation	Gas Loss	System Mass	Safety & Mission Assurance	Programmatic
Airlock(basis)						
Suitlock						
Suitport-Airlock						

Airsave

	EVA Overhead Time	Dust Mitigation	Gas Loss	System Mass	Safety & Mission Assurance	Programmatic
Airlock						
Suitlock						
Suitport-Airlock						

Takeaways

- **Suitport-Airlock offers some performance advantage over baseline Airlock configuration.**
  - Improves dust protection
  - Reduces EVA overhead time
  - Reduces total consumables resupply mass
- **However, Suitport-Airlock presents challenges.**
  - More complex development and integration
  - Increased system complexity
- **Suitlock offers lesser performance advantage**
  - Improves dust protection for crew entry but retains dust issues for logistics and maintenance
  - Limited EVA overhead time benefit
  - No consumables mass benefit over Airlock
  - Unique development